REVIEW ARTICLE

The Epidemiology of Methicillin-Resistant Staphylococcus aureus (MRSA) in Germany

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SUMMARY

Background: For decades, methicillin-resistant Staphylococcus aureus (MRSA) has been a major cause of infection in hospitals and nursing homes (health care-associated MRSA, HA-MRSA). Beginning in the late 1990s, many countries have also experienced a rising incidence of MRSA infection outside of the health care setting (community-associated MRSA, CA-MRSA). Moreover, animal reservoirs are increasingly considered to represent an important source of human MRSA acquisition. In this review article the authors describe the current epidemiological situation of MRSA in Germany.

Methods: This review is based on pertinent articles published up to 2010 that were retrieved by a selective PubMed search, as well as on publications issued by national reference institutions up to 2010.

Results: There are about 132 000 cases of MRSA in German hospitals each year. MRSA is found in about 18% to 20% of all inpatient-derived culture specimens that are positive for S. aureus. CA-MRSA is not yet endemic in Germany; important risk factors for its acquisition include travel to high-prevalence areas and household contact with persons that harbor a CA-MRSA infection. Agricultural livestock is the main animal reservoir for MRSA, which is often zoonotically transmitted from animals to human beings by direct contact. However, both CA-MRSA and MRSA from animal reservoirs can be imported into hospitals and cause nosocomial infections.

Conclusion: Hospitals and nursing homes were once the main reservoirs of MRSA, but new ones have now emerged outside of the healthcare setting. Efforts to prevent MRSA and limit its spread must rise to this new challenge.

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Methicillin-resistant *Staphylococcus aureus* (MRSA) is the most common multidrug-resistant pathogen causing nosocomial infections in Europe (1). Estimates indicate that there are approximately 170 000 MRSA infections in European healthcare systems each year, causing more than 5000 fatalities, more than 1 million additional inpatient days, and additional costs of approximately €380 million (1). However, for a number of years several countries have also been reporting successes in the prevention and control of health care-associated MRSA (HA-MRSA) infections. At the same time, new MRSA reservoirs outside hospitals have also been identified. In addition to community-associated MRSA (CA-MRSA) infections among the general population, these new reservoirs also include companion animals and agricultural livestock (hence the term livestock-associated MRSA, or LA-MRSA) and humans who come into contact with them.

Aims

The aim of this review article is to describe the current epidemiological status of methicillin-resistant *S. aureus* strains in Germany. In addition to the situation in healthcare facilities, the incidence of MRSA in the general population and in animal reservoirs will be highlighted, and the issues that arise from this and the conclusions for prevention will be discussed.

Methods

Epidemiological parameters are summarized on the basis of a selective review of the literature in PubMed (search term "MRSA AND Germany") and publications issued by national reference institutions (the Robert Koch Institute, the German National Reference Center for the Surveillance of Nosocomial Infections [Nationales Referenzzentrum für Surveillance von nosokomialen Infektionen], and the Federal Institute for Risk Assessment [Bundesinstitut für Risikobewertung]). This includes literature published up to and including 2010, not limited to a specific study type.

TABLE 1

MRSA prevalence on admission and at particular points in time in systematic screening of patients and residents of hospitals, homes for the elderly, and care homes in Germany

Study (year of investigation, type)[*1]	Region	Area[*2]	No. of facilities[*3]	No. of examined patients	Prevalence
Hospitals					
MRSA KISS reference data (2009, A)	Germany	All patients	199	–[*4]	0.66%
Reich-Schupke et al. (2008, A)	Bochum	Dermatology	1	384	3.1%
Grabe et al. (2008, A)	Siegen-Wittgenstein	All patients	14	6985	1.4%
Woltering et al. (2006)[*5]	Höxter	All patients	5	494	3.4%
Schulz et al. (2006/7, A)	Marburg	Surgery	1	442	3.9%
Köck et al. (2006, A)	Münsterland	All patients	39	25 540	1.6%
Chaberny et al. (2005)	Hannover	All patients	1	509	5.3%
Homes for the elderly, care homes					
Woltering et al. (2006)[*5]	Höxter	Home for the elderly/ care home	6	265	2.3%
Martin et al. (2004)[*2]	Duisburg	Home for the elderly/ care home	3	65	9%
Daeschlein et al. (2003)	Chemnitz	Home for the elderly/ care home	3	500	0%
Neuhaus et al. (2000/2001)	North Rhine-Westphalia (NRW)	Home for the elderly/ care home	61	1057	3.1%
Robert Koch Institute (1999/2000)	Brandenburg, Berlin, NRW, Hessen	Home for the elderly/ care home	32	1342	2.4%
von Baum et al. (1999/2000)	Rhine-Neckar region, Heidelberg	Home for the elderly/ care home	47	3 236	1.1%
Höpken et al. (1999/2000)[*6]	Lower Saxony	Home for the elderly/ care home	1	33/346	21/26%[6]
Heudorf et al. (1999)	Frankfurt	Home for the elderly/ care home	7	359	2.2%

[*1] Classified by year of investigation, type of investigation: if prevalence was ascertained on admission, this is indicated by the letter A (admission); data from sources [10, 13–24) and www.nrz-hygiene.de/surveillance/kiss/mrsa-kiss/; [*2] Area of investigation; [*3] Number of participating facilities; [*4] Data not available; [*5] Date added following personal correspondence with the authors; [*6] Investigated at two separate points in time

MRSA in hospitals, homes for the elderly, and care homes

Hospitals and other healthcare facilities (e.g. homes for the elderly and care homes) have been the traditional locations for MRSA infections for many decades. In terms of its incidence rate (the number of cases per 1000 patient days), MRSA remains the most common multidrug-resistant pathogen causing nosocomial infections in Germany (e1). Data from the European Antimicrobial Resistance Surveillance Network (EARS-Net) (e2) indicate that the proportion of MRSA among all *S. aureus* isolates from blood cultures in Germany has substantially increased in the 1990s and has now remained stable at 16–20% for several years. This trend is confirmed by data from the National Resistance Study of the Paul Ehrlich Society (PEG, Paul-Ehrlich-Gesellschaft) (e3). In that study, the proportion of MRSA among *S. aureus* isolates from clinical examination materials was 1.1% in 1990, had increased to 17.5% by 2001, and finally reached 20.3% in 2007. Current data from the Robert Koch Institute's (RKI) interactive Antibiotics Resistance Surveillance Database also indicate a relatively stable percentage of MRSA cases (all *S. aureus* isolates obtained from inpatients) for 2008 and 2009: 19.2% (2008) and 21.9% (2009) (RKI: https://ars.rki.de, last accessed on 30 November, 2010). In individual at-risk areas (e.g. intensive care units) in particular, however, higher MRSA rates (>37%) are reported (e4). A new data source on the number of invasive infections appeared in 2009, with the introduction of compulsory reporting by laboratories (according to Article 7 of the German Infection Protection Act) of MRSA detected in blood cultures and cerebrospinal fluid (CSF). More than 3000 cases have been reported in Germany via this system since it was introduced, corresponding to an incidence of 1.94/100 000 inhabitants (RKI: SurvStat, http://www3.rki.de/SurvStat, data as of December 15,

TABLE 2

Differences between MRSA subtypes

	HA-MRSA	CA-MRSA	LA-MRSA
PVL formation	Rare	Frequent	Single cases
Predominant clinical manifestation	Post-operative wound infections, osteomyelitis, pneumonia	Chronic skin infections, abscesses, pneumonia, fasciitis	Wound infections, respiratory-associated pneumonia
Indicators of frequency of infection in Germany	Approx. 14 000 healthcare-associated MRSA infections/ year (<5% of all nosocomial infections) (25)	2 to 3% of MRSA cases in Germany are PVL-positive (e11); overall incidence of CA-MRSA infections unknown	<1% of health care-associated MRSA infections; number of infections in outpatients unknown (11)
Risk factors	Hospital stays, residents of homes for the elderly/care homes, catheters, chronic wounds, antibiotic treatment	Travel to high-risk areas, contact with individuals infected with CA-MRSA	Direct contact with agricultural livestock (e.g. farmers, veterinarians, abattoir employees)
Prevention	Screening on or before hospital admission, measures to cure colonization, particularly hygiene measures in healthcare facilities according to RKI recommendations	Washing clothes, bedclothes, and towels at temperatures above 60 °C whenever possible; measures to cure colonization where appropriate	Careful cleanliness of animal enclosures, measures to cure colonization before elective surgery

PVL: Panton-Valentine leukocidin; MRSA: methicillin-resistant Staphylococcus aureus; HA-MRSA: health care-associated MRSA; CA-MRSA: community-associated MRSA; LA-MRSA: livestock-associated MRSA (11, 25, e11)

2010) with data from some German federal states not yet examined. By way of comparison, the incidence of hospital-associated MRSA bacteremia in England and the USA in 2006 and 2007 was between 7.2 and 7.8/100 000 inhabitants (e5). On the basis of the results of the MRSA module of Germany's Hospital Infection Surveillance System (KISS, Krankenhaus-Infektions-Surveillance-System) (http://www.nrz-hygiene.de), the annual number of MRSA cases in German hospitals (2008) is estimated at approximately 132 000 (including both colonizations and infections), and the number of nosocomially-acquired infections at 34 000 (2). In 2009, the mean MRSA incidence rate (both colonizations and infections) in the 199 hospitals that take part in KISS was 1.14/1000 patient days. Most patients had already been colonized at the time of admission to hospital (79.5% imported cases); 20.5% of cases were classified as "nosocomially-acquired" (e6). One marker of the entry of MRSA into hospitals is the prevalence on admission *(Table 1)*. Residents of care homes and homes for the elderly are high-risk groups for MRSA acquisition. Overall, several studies, most of them old, indicate an MRSA prevalence rate (including colonizations) of approximately 1 to 3% *(Table 1)*, with high levels of local variability (17, 22).

MRSA in the general population

Until the 1990s, MRSA infections were only sporadically described outside the health care setting. Since then, in some countries an increasing number of CA-MRSA infections has been documented. CA-MRSA is defined as MRSA detected in outpatients or in inpatients in the first 48 to 72 hours after hospital admission, provided patients have no traditional risk factors for healthcare-associated MRSA (history of MRSA, contact with MRSA, previous hospital or care home stay, dialysis) (3).

A particularly high number of CA-MRSA infections is described in the USA, where CA-MRSA is now the most common pathogen (>50%) causing skin and soft tissue infections (particularly abscesses) acquired by outpatients, the number of these infections has nearly doubled in six years, and the main burden of MRSA infections, measured as the incidence per 100 000 inhabitants, now falls on the general population (3). In addition, CA-MRSA is imported into hospitals and causes nosocomial infections (3), so the above-mentioned epidemiological definition of CA-MRSA is becoming increasingly inaccurate. However, CA-MRSA is also molecularly different from HA-MRSA: the increase of MRSA outside hospitals in the USA is caused mainly by the epidemic spread of two clonal lines of MRSA (USA300/ST8 and USA400/ST1), which can usually form the toxin Panton-Valentine leukocidin (PVL) (3, 4) *(Table 2)*. Due to cytotoxic effects, particularly on neutrophil granulocytes, PVL contributes to the virulence of *S. aureus* (4). In contrast to the USA, the CA-MRSA clones detected in Germany to date are heterogeneous *(Table 3)*. Cases of necrotizing pneumonia (e7, e8) and fasciitis/myositis (e9) caused by these strains of *S. aureus* are much rarer than PVL-associated skin manifestations, but often peracute and associated with high mortality rates (>30%).

The illness burden caused by CA-MRSA in Germany is currently significantly smaller than in the USA. In the 1990s, a multicenter study detected PVL-encoding genes in 0.9% (blood culture isolates) and 1.4% (nasal swab isolates) of *S. aureus* (e10). A prospective study of 248 patients with skin infections in

TABLE 3

Molecular characteristics of CA-MRSA detected in Germany and phenotypic antibiotic resistance of PVL-forming MRSA at Münster University Hospital, 2007 to 2010

Typical CA-MRSA clone[*1]	Distribution area outside Germany
ST80/t044 ("European CA-MRSA")	Austria, Belgium, Denmark, France, Switzerland, the Netherlands, Sweden
ST8/t008 ("USA300")	USA, Sweden, Denmark
ST22/t310	Scotland
ST1/t127 ("USA400")	USA
ST152/t355	Kosovo, Serbia, Croatia, Slovenia
ST5/t002	The Netherlands, Belgium, Slovenia, south-east Europe
ST30/t019, t021	USA, Oceania, Belgium, Denmark, the Netherlands, Sweden
Antibiotic	**Percentage of resistant isolates[*2]**
Gentamicin	17%
Erythromycin	25%
Clindamycin	19%
Tetracyclin	19%
Levofloxacin	21%
Fusidic acid	17%
Trimethoprim/sulfamethoxazole	10%
Rifampicin, vancomycin, linezolid, mupirocin	0%

[*1] Data adapted according to [11-12]; information given includes multilocus sequence type (ST)/S. aureus protein A gene (spa) type, abbreviated as tXXX, and any further indications in parentheses;
[*2] n = 52 PVL-positive MRSA isolates (2007 to 2010) from routine diagnoses at Münster University Hospital

an outpatient dermatology clinic has shown that PVL-forming CA-MRSA accounted for 22% of all MRSA cases, 3% of all patients with *S. aureus*, and 1.6% of all patients with skin infections (5). In 4815 MRSA isolates with suspected CA-MRSA infection sent by 145 laboratories to the German reference center for staphylococci, PVL-encoding genes were found in 1.8% (2005) and 3.1% (2006), which indicates that most cases of MRSA infection that occur outside hospitals are caused by traditional HA-MRSA clones that were previously acquired in healthcare facilities (e11). A study (2002 to 2004) of more than 1400 children (one of the main high-risk groups in the USA) in the Freiburg region also yielded a prevalence of MRSA of 0.3% (with no further classification of the MRSA strains found) (e12). However, CA-MRSA outbreaks with high numbers of colonization and infection were also described (e13). Although the current incidence of PVL-forming MRSA infections in Germany is low, it is important to state here that methicillin-susceptible variants of *S. aureus* (MSSA) can also produce PVL. As a result, PVL-associated infections must be considered in cases of recurrent abscesses, in particular, even in immunocompetent patients (e14, e15).

The currently low burden of CA-MRSA illness in Germany makes it difficult to provide precise definitions of high-risk groups for such infection. In the USA, high numbers of CA-MRSA infections have been observed where people live in close proximity to one another (barracks, prisons, households), engage in sports in which skin abrasions are common (soccer, rugby), or share items of personal hygiene (e.g. towels). HIV-positive individuals and men who have sex with men have also been stated to be high-risk populations (3). In the context of the current epidemiological status of CA-MRSA in Germany, these groups do not constitute high-risk groups *per se* (although single cases have been described [e16]). Various European studies have found a high risk of CA-MRSA acquisition among those who travel to high-prevalence areas (e17–e19). This is confirmed by a study conducted in Bavaria, in which 14 of 39 cases of CA-MRSA were either associated with travel or occurred in individuals living in Germany but of Mediterranean (particularly Greek, Turkish, or Italian) family origin (e20). In fact, Greece in particular seems to be a European hotspot for CA-MRSA, as infection rates there are similar to those in the USA. In addition, CA-MRSA infections are detected more frequently in those returning from travel to East Asia, Oceania, Africa, and the Middle East. A further risk factor for CA-MRSA in Germany is close contact (the same household) with persons infected with CA-MRSA, as studies of CA-MRSA index cases have shown that the pathogen was transmitted to other members of the same household in 43 to 47% of cases (e21, e22), with 67% of all household contacts testing positive for MRSA (e21).

MRSA in animals

MRSA colonizations and infections have been described in a range of animal species. In recent years, studies have concentrated on livestock (swine, cattle, poultry). As a result, the term "livestock-associated" MRSA (LA-MRSA) is often used to describe these isolates. It has been established that LA-MRSA strains can be detected in 43 to 70% of pig farms in Germany (e23, e24), and that up to 71% of individual animals in abattoirs have been colonized (6). In addition to swine, MRSA has also been detected in cattle (7, 8), poultry flocks, and samples of chicken meat (7). Although there have been individual reports of livestock infected with LA-MRSA (e25, e26), most colonized animals are asymptomatic. Molecular analysis of MRSA isolates from livestock shows that most cases (>90% in swine) are caused by one specific clonal complex of MRSA (CC398). These cases of MRSA from animal reservoirs are therefore different from human HA- and CA-MRSA *(Table 2)*. In addition to livestock, MRSA has also been detected in companion animals. For example, outbreaks of nosocomial MRSA infection in Germany have been detected in horses at veterinary hospitals (8, e27, e28), and MRSA has been described in dogs, cats, pigeons, and guinea pigs (e29–e31). In contrast to livestock, where the clonal line CC398 is predominant,

TABLE 4

MRSA in Germany

Population 82 000 000	More than 160 000 000 heads of livestock		
– Hospital: approx. 132 000 cases of MRSA (colonization and infection)		**No. of animals**	**MRSA-positive**
– Home for the elderly: approx. 7100 MRSA carriers	Horses	541 900	n/a[*1]
– CA-MRSA: approx. 1 to 2% of individuals with skin infections	Cattle	12 686 000	Approx. 30%
– LA-MRSA: colonization of up to 86% of farmers in direct contact with animals; >4% of relatives of farmers; CC398 cases as a proportion of all MRSA cases on hospital admission in region with high livestock numbers 17%	Dairy cows	4 071 200	Approx. 5 to 17%[*2]
	Sheep	2 537 800	n/a[*1]
	Swine	27 125 300	Approx. 70%
	Poultry	111 522 600	n/a[*1]
	Approx. 27 000 000 companion animals		
	Individual cases of MRSA described, no data available on prevalence		

[*1] n/a: No data available but detected cases described; [*2] In milk samples

MRSA clones found among companion animals are often typical human molecular lines indicating a transmission from human to pets rather than vice versa. (e32).

MRSA from zoonotic reservoirs in humans

Numerous studies show that clonal line CC398 MRSA can be transmitted from animals to humans. In connection with this it has been shown that 86% of pig farmers in Germany are carriers of nasal MRSA (9). Veterinarians (12 to 45%) (9) and relatives of pig farmers who do not themselves come into regular direct contact with animals (4%) were also frequently colonized in these studies (9). In regions with high numbers of livestock (e.g. Lower Saxony or Westphalia in Germany), CC398 isolates are often imported into healthcare facilities. For example, amongst MRSA from screenings in the Münsterland region (hospitals belonging to the quality network EUREGIO MRSA-net), this particular MRSA clone accounted for 17% of all MRSA cases in 2006 (10). In this region, contact with swine and cattle represented independent risk factors for MRSA CC398 colonization on hospital admission (e24).

Although many publications have documented MRSA CC398's potential for causing infections (endocarditis, pneumonia, wound infections) in humans (1), as yet there is no systematic summary of the incidence of MRSA infections in the high-risk groups mentioned above. It is therefore currently impossible to estimate whether farmers or other exposed persons suffer from MRSA infections more frequently than the general population. MRSA CC398 represents a total of approximately 0.6% of all human (mostly nosocomial) MRSA isolates examined at the national reference center for staphylococci between 2006 and 2008 (11). A Europe-wide study of MRSA blood culture isolates also concluded that MRSA CC398 accounted for less than 1% of all MRSA cases (e33). This indicates that the numbers of hospital infections caused by MRSA CC398 are as yet low, despite the higher colonization rates for particular high-risk groups and the importation of these strains into hospitals. However, there are substantial regional variations. In the Münsterland region, MRSA CC398 accounted for 4.3% of all MRSA cases from clinical materials between 2006 and 2008 (e34).

The risk of foodborne infections due to MRSA is currently judged by the monitoring authorities to be low (e35, e36). Although MRSA (mostly CC398) has been detected in beef, veal, lamb, pork, chicken, turkey, other poultry, and game on the retail market (7), quantitative investigation indicates low-grade contamination. There is no evidence of infection associated with contact with or consumption of food contaminated with MRSA (7).

Discussion and conclusions for prevention and control

Hospitals, homes for the elderly, and care homes

The number of MRSA infections in German hospitals seems to have stabilized. Despite several reports of success (e37, e38), as yet no significant impact has been achieved in Germany as a whole on the overall incidence of health care-associated MRSA infections as it has in other European countries (e.g. Britain, France, Belgium) (1). This explains the need for further improvement of the implementation of control measures locally, and within the regional networks for MRSA prevention that are currently established in most German federal states (e39–e41). Detailed recommendations on handling MRSA patients in homes for the elderly and care homes exist; there are national recommendations for defining which patients belong to high-risk groups and should therefore be tested for MRSA colonization when admitted to the hospital (e42). However, structural shortcomings still make it difficult to take measures to cure MRSA colonization and to control it in this area of health care. For the first

time in Germany, as part of the projects EUREGIO MRSA-net (e43) and EurSafety Health-net (www.mrsa-net.eu; http://www.eursafety.eu/index.html), in the territory covered by the Westphalia–Lippe Association of Statutory Health Insurance Physicians (KVWL, Kassenärztliche Vereinigung Westfalen-Lippe) icon numbers have been created so that the number of MRSA patients being treated on an outpatient basis can be determined. Treatment costs can also be measured, particularly costs associated with laboratory tests. There is also the possibility that drugs needed to eradicate MRSA (e.g. mupirocin nasal ointment) might be removed from the medication budget of practicing physicians, if there is a test of cost-effectiveness. Swab tests that are part of the monitoring of curative treatment do not conflict with cost-effectiveness incentives. However, as yet, these regulations apply only in the territory covered by the KVWL, not in the rest of Germany.

The general population

There are no indications as yet that CA-MRSA is spreading to the German population. However, the fact that individual areas with higher prevalences of CA-MRSA have been identified even in Europe does make CA-MRSA infection increasingly likely. CA-MRSA should therefore be one of the possibilities considered in patients with compatible travel history and/or clinical symptoms, particularly patients with recurrent abscess-type skin inflammation. Because infection is frequently transmitted to other members of the same household, such persons should also be considered for diagnosis and treatment, particularly in cases in which multiple curative treatment attempts have failed. Appropriate classification by means of molecular typing should be arranged for suspected CA-MRSA isolates. Antibiotic treatment of CA-MRSA infections in outpatients is usually uncomplicated, because several antibiotics that can be taken orally are available *(Table 3)*. There are recommendations on handling CA-MRSA in the home environment available in German (12).

Animal reservoirs

The significance of zoonotic transmission of multidrug-resistant bacterial pathogens is becoming increasingly clear *(Table 4)*. This also reflects the number of projects currently being conducted by German research associations on the subject (http://www.zoonosen.net/). For example, the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV, Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) is currently sponsoring five projects on MRSA in livestock rearing, while the Federal Ministry of Education and Research (BMBF, Bundesministerium für Bildung und Forschung) is sponsoring a research association (Med-Vet-Staph) to determine the virulence, pathogenicity, transmissibility, and epidemiology of S. aureus/MRSA in animal reservoirs.

KEY MESSAGES

- The overall incidence of health care-associated MRSA infections in Germany has stabilized, following a steep increase in the 1990s. The number of MRSA cases (colonizations and infections) in German hospitals is estimated at 132 000.
- The prevalence of MRSA in homes for the elderly and care homes is approximately 1 to 2% of residents, with substantial local variation.
- At the molecular level, community-associated MRSA (CA-MRSA) is usually characterized by the toxin Panton-Valentine leukocidin (PVL).
- MRSA is widespread in various different species of livestock; the dominant strain is currently the MRSA clone CC398, which is easily transmitted to humans in direct contact with livestock.
- MRSA has been occasionally detected in companion animals, but there are no accurate data for Germany on its frequency in these animals.

Conflict of interest statement

Dr. Köck has received lecture fees from Pfizer Europe.

Dr. Kipp has received reimbursement of expenses from Astellas, MSD, Wyeth, and Novartis.

Prof. Dr. Friedrich has received reimbursement of expenses from Siemens.

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PD Dr. Mellmann and Dr. Schaumburg declare that no conflict of interest exists.

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REFERENCES

1. Köck R, Becker K, Cookson B, et al.: Methicillin-resistant Staphylococcus aureus (MRSA): burden of disease and control challenges in Europe. Euro Surveill 2010; 15(41): 19688.
2. Mielke M, Bölt U, Geffers C: Basisdaten der stationären Krankenversorgung in Deutschland – nosokomiale Infektionen. Epidemiologisches Bulletin 2010; 36: 359–68.
3. David MZ, Daum RS: Community-associated methicillin-resistant Staphylococcus aureus: epidemiology and clinical consequences of an emerging epidemic. Clin Microbiol Rev 2010; 23: 616–87.
4. Löffler B, Hussain M, Grundmeier M, et al.: Staphylococcus aureus panton-valentine leukocidin is a very potent cytotoxic factor for human neutrophils. PLoS Pathog 2010; 6: e1000715.
5. Jappe U, Heuck D, Strommenger B, et al.: Staphylococcus aureus in dermatology outpatients with special emphasis on community-associated methicillin-resistant strains. J Invest Dermatol 2008; 128: 2655–64.
6. Tenhagen BA, Fetsch A, Stuhrenberg B, et al.: Prevalence of MRSA types in slaughter pigs in different German abattoirs. Vet Rec 2009; 165: 589–93.
7. Bundesinstitut für Risikobewertung: Menschen können sich über den Kontakt mit Nutztieren mit Methicillin-resistenten Staphylococcus aureus (MRSA) infizieren. Stellungnahme 014/2009. www.bfr.bund.de/cm/208/menschen_koennen_sich_ueber_den_kontakt_mit_nutztieren_mit_mrsa_infizieren.pdf.

8. Spohr M, Rau J, Friedrich A, et al.: Methicillin-Resistant Staphylococcus aureus (MRSA) in three dairy herds in Southwest Germany. Zoonoses Public Health 2011; 58(4): 252–61.
9. Cuny C, Nathaus R, Layer F, Strommenger B, Altmann D, Witte W: Nasal colonization of humans with methicillin-resistant Staphylococcus aureus (MRSA) CC398 with and without exposure to pigs. PLoS One 2009; 4: e6800.
10. Köck R, Brakensiek L, Mellmann A, et al.: Cross-border comparison of the admission prevalence and clonal structure of meticillin-resistant Staphylococcus aureus. J Hosp Infect 2009; 71: 320–6.
11. Robert Koch-Institut: FG Nosokomiale Infektionen des RKI: Auftreten und Verbreitung von MRSA in Deutschland 2008. Epidemiologisches Bulletin 2009; 17: 155–64.
12. Witte W, Mielke M: Community MRSA. Zentralbl Chir 2007; 132: 124–9.
13. Reich-Schupke S, Geis G, Reising M, Altmeyer P, Stucker M: MRSA in dermatology – Prospective epidemiological study in employees and patients of a dermatological department of a university hospital. J Dtsch Dermatol Ges 2010; 8: 607–13.
14. Grabe C, Buckard R, El-Ansari T, Käflein R: Flächendeckendes einmonatiges MRSA-Prävalenzscreening in Akut- und Rehakliniken in Siegen-Wittgenstein. Epidemiologisches Bulletin 2010; 18: 163–70.
15. Schulz M, Nonnenmacher C, Mutters R: Cost-effectiveness of rapid MRSA screening in surgical patients. Eur J Clin Microbiol Infect Dis 2009; 28: 1291–6.
16. Woltering R, Hoffmann G, Daniels-Haardt I, Gastmeier P, Chaberny IF: Prevalence of methicillin-resistant Staphylococcus aureus (MRSA) in patients in long-term care in hospitals, rehabilitation centers and nursing homes of a rural district in Germany. Dtsch Med Wochenschr 2008; 133: 999–1003.
17. Martin U, Sonntag AK, Neuhaus B, Karch H: Surface disinfection in nursing homes--what is really happening? Study of control success in three Duisburg nursing homes. Gesundheitswesen 2004; 66: 682–7.
18. Daeschlein G, Assadian O, Rangous I, Kramer A: Risk factors for Staphylococcus aureus nasal carriage in residents of three nursing homes in Germany. J Hosp Infect 2006; 63: 216–20.
19. Neuhaus B, Bocter N, Braulke C, Heuck D, Witte W: Studie zum Vorkommen von Methicillin-resistenten S. aureus in Alten- und Pflegeheimen in Nordrhein-Westfalen. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2002; 45: 894–904.
20. Robert Koch-Institut: Nationales Referenzzentrum für Staphylokokken am RKI: Methicillin-resistente Staphylococcus aureus (MRSA) in deutschen Alten- und Pflegeheimen – zur Situation. Epidemiologisches Bulletin 2003; 19: 145–9.
21. von Baum H, Schmidt C, Svoboda D, Bock-Hensley O, Wendt C: Risk factors for methicillin-resistant Staphylococcus aureus carriage in residents of German nursing homes. Infect Control Hosp Epidemiol 2002; 23: 511–5.
22. Höpken ME, Dreesman J, Braulke C, Heuck D, Witte W: MRSA Besiedlung in einem Alten- und Pflegeheim: Risikofaktoren und Prävalenz. Hyg Med 2001; 26: 225–30.
23. Heudorf U, Bremer V, Heuck D: Methicillin-resistant Staphylococcus aureus in long-term care facilities for the aged in Frankfurt am Main, Germany, in 1999. Gesundheitswesen 2001; 63: 447–54.
24. Chaberny IF, Bindseil A, Sohr D, Gastmeier P: A point-prevalence study for MRSA in a German university hospital to identify patients at risk and to evaluate an established admission screening procedure. Infection 2008; 36: 526–32.
25. Gastmeier P, Geffers C: Nosocomial infections in Germany. What are the numbers, based on the estimates for 2006? Dtsch Med Wochenschr 2008; 133: 1111–5.

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REVIEW ARTICLE

The Epidemiology of Methicillin-Resistant Staphylococcus aureus (MRSA) in Germany

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eReferences

e1. Kohlenberg A, Schwab F, Meyer E, Behnke M, Geffers C, Gastmeier P: Regional trends in multidrug-resistant infections in German intensive care units: a real-time model for epidemiological monitoring and analysis. J Hosp Infect 2009; 73: 239–45.

e2. European Antimicrobial Resistance Surveillance System (EARSS): EARSS Annual Report 2008. www.ecdc.europa.eu/en/activities/surveillance/EARS-Net/Documents/2008_EARSS_Annual_Report.pdf.

e3. Kresken M, Hafner D, Schmitz FJ, Wichelhaus TA, für die Studiengruppe Resistenzsituation bei klinisch wichtigen Infektionserregern gegenüber Antibiotika in Deutschland und im mitteleuropäischen Raum: Bericht über die Ergebnisse einer multizentrischen Studie der Arbeitsgemeinschaft Empfindlichkeitsprüfungen & Resistenz der Paul-Ehrlich-Gesellschaft für Chemotherapie e.V. aus dem Jahre 2007. Antiinfectives Intelligence, Rheinbach 2009.

e4. Kohlenberg A, Schwab F, Geffers C, Behnke M, Ruden H, Gastmeier P: Time-trends for Gram-negative and multidrug-resistant Gram-positive bacteria associated with nosocomial infections in German intensive care units between 2000 and 2005. Clin Microbiol Infect 2008; 14: 93–6.

e5. Lessa FC, Mu Y, Davies J, et al.: Comparison of incidence of bloodstream infection with methicillin-resistant Staphylococcus aureus between England and United States, 2006–2007. Clin Infect Dis 2010; 51: 925–8.

e6. Nationales Referenzzentrum für Surveillance von nosokomialen Infektionen. Krankenhaus-Infektions-Surveillance-System: Modul MRSA-KISS Referenzdaten Berechnungszeitraum: 1st January 2009 - 31st Dezember 2009. www.nrz-hygiene.de/surveillance/kiss/mrsa-kiss/.

e7. Gillet Y, Issartel B, Vanhems P, et al.: Association between Staphylococcus aureus strains carrying gene for Panton-Valentine leukocidin and highly lethal necrotising pneumonia in young immunocompetent patients. Lancet 2002; 359: 753–9.

e8. Hörnig-Franz I, Kahl BC, Tebbe W, et al.: Nekrotisierende Pneumonie mit Staphylococcus aureus (pvl-Gen positiv). Letal verlaufende Pneumonie bei einem 12-jährigen immunkompetenten Mädchen. Monatsschr Kinderheilkd 2007; 155: 10–15.

e9. Miller LG, Perdreau-Remington F, Rieg G, et al.: Necrotizing fasciitis caused by community-associated methicillin-resistant Staphylococcus aureus in Los Angeles. N Engl J Med 2005; 352: 1445–53.

e10. von Eiff C, Friedrich AW, Peters G, Becker K: Prevalence of genes encoding for members of the staphylococcal leukotoxin family among clinical isolates of Staphylococcus aureus. Diagn Microbiol Infect Dis 2004; 49: 157–62.

e11. Witte W, Strommenger B, Cuny C, Heuck D, Nuebel U: Methicillin-resistant Staphylococcus aureus containing the Panton-Valentine leucocidin gene in Germany in 2005 and 2006. J Antimicrob Chemother 2007; 60: 1258–63.

e12. Fluegge K, Adams B, Luetke Volksbeck U, Serr A, Henneke P, Berner R: Low prevalence of methicillin-resistant Staphylococcus aureus (MRSA) in a southwestern region of Germany. Eur J Pediatr 2006; 165: 688–90.

e13. Wagenlehner FM, Naber KG, Bambl E, et al.: Management of a large healthcare-associated outbreak of Panton-Valentine leucocidin-positive meticillin-resistant Staphylococcus aureus in Germany. J Hosp Infect 2007; 67: 114–20.

e14. Kola A, Hübschmann K,Behl ES, et al.: Hautabszesse bei Kindergartenkindern: Schwere Verläufe durch Panton-Valentine-Leukozidin-bildenden Staphylococcus aureus. Klin Padiatr 2010; 222: 319–20.

e15. Vonberg RP, Sedlasek L, Chaberny IF, Suerbaum S, Gastmeier P, Linde HJ: Multiple Abszesse bei immunkompetenten Patienten durch Panton-Valentin-Leukozidin-positiven Staphylococcus aureus. Hautarzt 2008; 59: 319–22.

e16. Witte W.: Zum Auftreten von caMRSA „USA300“ bei MSM in Deutschland. Epidemiologisches Bulletin 2008; 11: 85–94.

e17. Holzknecht BJ, Hardardottir H, Haraldsson G, et al.: Changing epidemiology of methicillin resistant Staphylococcus aureus in Iceland 2000–2008 challenges current guidelines. J Clin Microbiol 2010; 48(11): 4221–7.

e18. Stenhem M, Ortqvist A, Ringberg H, et al.: Imported methicillin-resistant Staphylococcus aureus, Sweden. Emerg Infect Dis 2010; 16: 189–96.

e19. Longtin Y, Sudre P, Francois P, et al.: Community-associated methicillin-resistant Staphylococcus aureus: risk factors for infection, and long-term follow-up. Clin Microbiol Infect 2009; 15: 552–9.

e20. Maier J, Melzl H, Reischl U, et al.: Panton-Valentine leukocidin-positive methicillin-resistant Staphylococcus aureus in Germany associated with travel or foreign family origin. Eur J Clin Microbiol Infect Dis 2005; 24: 637–9.

e21. Mollema FP, Richardus JH, Behrendt M, et al.: Transmission of methicillin-resistant Staphylococcus aureus to household contacts. J Clin Microbiol 2010; 48: 202–7.

e22. Johansson PJ, Gustafsson EB, Ringberg H: High prevalence of MRSA in household contacts. Scand J Infect Dis 2007; 39: 764–8.

e23. European Food Safety Authority: Analysis of the baseline survey on the prevalence of methicillin-resistant Staphylococcus aureus (MRSA) in holdings with breeding pigs, in the EU, 2008, Part A: MRSA prevalence estimates; on request from the European Commission. EFSA Journal 2009; 7: 1376.

e24. Köck R, Harlizius J, Bressan N, et al.: Prevalence and molecular characteristics of methicillin-resistant Staphylococcus aureus (MRSA) among pigs on German farms and import of livestock-related MRSA into hospitals. Eur J Clin Microbiol Infect Dis 2009; 28: 1375–82.

e25. Fessler A, Scott C, Kadlec K, Ehricht R, Monecke S, Schwarz S: Characterization of methicillin-resistant Staphylococcus aureus

ST398 from cases of bovine mastitis. J Antimicrob Chemother 2010; 65: 619–25.

e26. Meemken D, Blaha T, Tegeler R, et al.: Livestock associated Methicillin-Resistant Staphylococcus aureus (LaMRSA) isolated from lesions of pigs at necropsy in Northwest Germany between 2004 and 2007. Zoonoses Public Health 2010; 57: e143–8.

e27. Cuny C, Strommenger B, Witte W, Stanek C: Clusters of infections in horses with MRSA ST1, ST254, and ST398 in a veterinary hospital. Microb Drug Resist 2008; 14: 307–10.

e28. van Duijkeren E, Moleman M, Sloet van Oldruitenborgh-Oosterbaan MM, et al.: Methicillin-resistant Staphylococcus aureus in horses and horse personnel: an investigation of several outbreaks. Vet Microbiol 2010; 141: 96–102.

e29. Strommenger B, Kehrenberg C, Kettlitz C, Cuny C, Verspohl J, Witte W, et al.: Molecular characterization of methicillin-resistant Staphylococcus aureus strains from pet animals and their relationship to human isolates. J Antimicrob Chemother 2006; 57: 461–5.

e30. Walther B, Wieler LH, Friedrich AW, et al.: Methicillin-resistant Staphylococcus aureus (MRSA) isolated from small and exotic animals at a university hospital during routine microbiological examinations. Vet Microbiol 2008; 127: 171–8.

e31. Walther B, Wieler LH, Friedrich AW, Kohn B, Brunnberg L, Lübke-Becker A: Staphylococcus aureus and MRSA colonization rates among personnel and dogs in a small animal hospital: association with nosocomial infections. Berl Munch Tierarztl Wochenschr 2009; 122: 178–85.

e32. Cuny C, Friedrich A, Kozytska S, et al.: Emergence of methicillin-resistant Staphylococcus aureus (MRSA) in different animal species. Int J Med Microbiol 2010; 300: 109–17.

e33. Grundmann H, Aanensen DM, van den Wijngaard CC, Spratt BG, Harmsen D, Friedrich AW: Geographic distribution of Staphylococcus aureus causing invasive infections in Europe: a molecular-epidemiological analysis. PLoS Med 2010; 7(1): e1000215.

e34. Van Cleef B, Monnet D, Voss A, et al.: Livestock-associated methicillin-resistant Staphylococcus aureus from human samples, Europe, 2007. Emerg Infect Dis 2011; 17(3): 502–5.

e35. European Centre for Disease Prevention and Control, European Food Safety Agency, European Medicines Agency: Joint scientific report of ECDC, EFSA and EMEA on meticillin resistant Staphylococcus aureus (MRSA) in livestock, companion animals and foods. www.efsa.europa.eu/en/efsajournal/pub/301r.htm.

e36. European Food Safety Authority (EFSA): Scientific Opinion of the Panel on Biological Hazards on a request from the European Commission on Assessment of the Public Health significance of meticillin resistant Staphylococcus aureus (MRSA) in animals and foods. www.efsa.europa.eu/en/efsajournal/doc/bio haz_op_993_mrsa_en,3.pdf?ssbinary=true

e37. Gastmeier P, Schwab F, Geffers C: MRSA-Reduktion auf KISS-Intensivstationen. Epidemiologisches Bulletin 2009; 29: 273–8.

e38. Trautmann M, Pollitt A, Loh U, et al.: Implementation of an intensified infection control program to reduce MRSA transmissions in a German tertiary care hospital. Am J Infect Control 2007; 35: 643–9.

e39. Chaberny IF, Wriggers A, Behnke M, Gastmeier P: Antibiotics: MRSA prevention measures in German hospitals: results of a survey among hospitals, performed as part of the MRSA-KISS module. Dtsch Arztebl Int 2010; 107: 631–7.

e40. Friedrich AW: Vom Papier zur Realität: Chancen regionaler Netzwerkbildung für die Prävention von MRSA. Krankenhhygup2date 2010; 5: 105–20.

e41. Robert Koch-Institut FG Angewandte Infektions- und Krankenhaushygiene des RKI.: Regionale Netzwerke: Instrumente zur Vermeidung der Weiterverbreitung von Erregern mit speziellen Resistenzen und Multiresistenzen. Epidemiologisches Bulletin 2009; 12: 105–16.

e42. Robert Koch-Institut: Kommentar zu den „Empfehlungen zur Prävention und Kontrolle von MRSA-Stämmen in Krankenhäusern und anderen medizinischen Einrichtungen". Epidemiologisches Bulletin 2008; 42: 363–4.

e43. Friedrich AW, Daniels-Haardt I, Köck R, et al.: EUREGIO MRSA-net Twente/Münsterland--a Dutch-German cross-border network for the prevention and control of infections caused by methicillin-resistant Staphylococcus aureus. Euro Surveill 2008; 13(35): pii: 18965.